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Magnetic properties of a mischmetal–cobalt alloy

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Abstract. The magnetic properties of a mischmetal-cobalt alloy are studied. A mischmetal-64% cobalt alloy was melted in induction furnace under a protective atmosphere of argon. The melt was solidified in a magnetic field of 7 kOe, and cooled to a temperature of 950° C and was thereafter quenched in water. Specimens of suitable dimensions were machined, heat-treated in the temperature range 1000–1100° C for various lengths of time and the magnetic properties evaluated. The $(BH)_{max}$ value was 10·3 MGOe which was associated with a B_r value of 7 kG and H_c value of 5 kOe. The results obtained offer feasibility to design new MM–Co_5 magnets through developments in processing technique.

Keywords. Solidification; atmosphere quenching.

1. Introduction

The fabrication of rare-earth-cobalt magnets possessing high energy product obtained by liquid phase sintering methods has been well understood. For instance Sm–Co has been reported to possess $(BH)_{max}$ of 20 MGOe (Buschow *et al* 1969). However, the cost of magnet based on pure rare-earth metals is high since the rare-earth constituents are expensive. It would be highly desirable to develop magnets possessing high energy product at a relatively lower cost. With this objective this study was undertaken with cerium mischmetal which is relatively cheaper and seems to be a potential component in conjuction with cobalt possessing a $(BH)_{max}$ of 20 MGOe (Strnat 1967). The main advantages in the development of MM–Co_5 magnets as compared with Sm–Co_5 are, lower raw materials cost, lower sintering temperatures and better mechanical properties.

Attempts to replace pure rare-earth metals either partially or entirely by mischmetal additions have been made by various investigators. An energy product of 15·2 MGOe (Martin *et al* 1971) has been reported by liquid-phase sintering method in an alloy containing equal parts of Sm and MM with cobalt. Improved magnetic properties (Kawaguchi *et al* 1970) have been obtained for a Cu–MM–Co alloy prepared by melting and casting method. MM–Co_5 alloy prepared by isostatic pressing (without sintering) has given a $(BH)_{max}$ of 3·1 MGOe (McCaig 1970), using liquid-phase sintering, a $(BH)_{max}$ of 4·4 MGOe (Benz *et al* 1971) has been

achieved in MM–Co_5 magnets. In an MM–Co_5 alloy a $(BH)_{max}$ of 8·8 MGOe (Fellow *et al* 1972) has been achieved by liquid phase sintering method. Using a single melt approach $(BH)_{max}$ of 10–12 MGO_e (Wells 1973) have also been reported. The present investigation is however confined to the development of magnetic properties of MM–Co_5 alloy.

2. Experimental

A mischmetal-64% cobalt alloy was prepared by induction melting using a protective atmosphere of argon in alumina crucible. The melt was solidified in a magnetic field of 7 kOe, and cooled to a temperature of 950° C and thereafter quenched in water. During solidification and cooling the pole pieces were well protected against radiated heat by (a) cooling the pole pieces by water circulation through copper tubing wound on them, and (b) placing asbestos sheet in the form of cylinder opened at both ends to accommodate the crucible containing the melt. Specimens 5 mm in diameter and 10 mm in length were machined for heat treatments and magnetic measurements. Specimens were annealed between 1000°–1100° C at 20° C intervals for a constant period of 60 min in an argon atmosphere. Further, the specimens were annealed ranging from 15 min to 120 min at some selected temperatures within the above specified range.

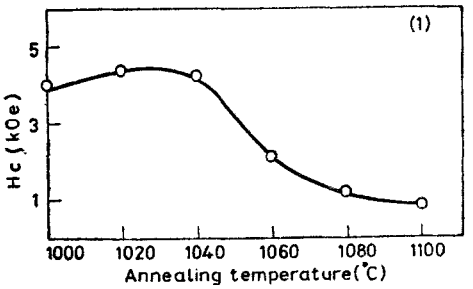
6. Results and discussion

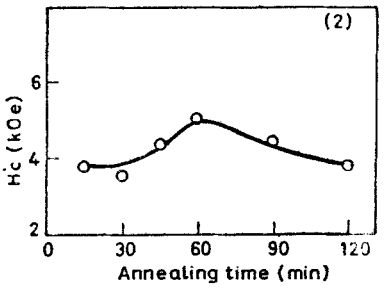
Figure 1 shows the variation of coercive force with temperature. The maximum in coercivity is observed at 1020° C with an H_c value of 4·4 kOe. The decrease of coercivity between 1000–1040° C is small. The coercivity, however, decreases fast by increase of temperature above 1040° C. Figure 2 shows the variations of coercivity with time for the specimens annealed at 1020° C. The coercivity decreases initially and then rises and approaches its maximum value of 5 kOe in 60 min. For the rest of the increased periods of annealing the decrease of coercivity is slow.

Figure 3 shows that the B_r value increases with increase in temperature but the increase is slow at higher temperatures. The variation of B_r with time (figure 4) at 1040° C shows a maximum in 30 min reaching a value of 7 kG.

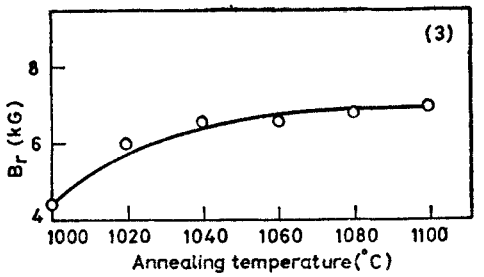
Figure 5 gives the variation of energy product $(BH)_{max}$ with temperature. A peak in the curve is noted at 1040° C acquiring a value of 9·2 MGOe. The variation of $(BH)_{max}$ with time is shown in figure 6 which shows that $(BH)_{max}$ has reached a value of 10·3 MGOe. Further decrease of $(BH)_{max}$ with time is slow.

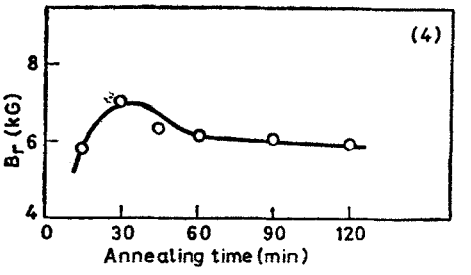
The response of the magnetic properties noted in this MM–Co_5 alloy appears to be dependent on the processing parameters associated with structural transformations occurring in this system. The structural changes occurring in this system are expected to be complex since the mischmetal is a cerium-rich alloy which, however, contains significant amounts of La, Nd and Pr. Moreover, it has already been reported (Buschow 1972, 1973) that all the RCo_5 alloys where R is a rare-earth metal, undergo eutectoid reaction like $RCo_5 \rightarrow R_2Co_{17} + R_2Co_7$. Since La, Nd, Pr and Ce are present in mischmetal such reactions are expected to affect



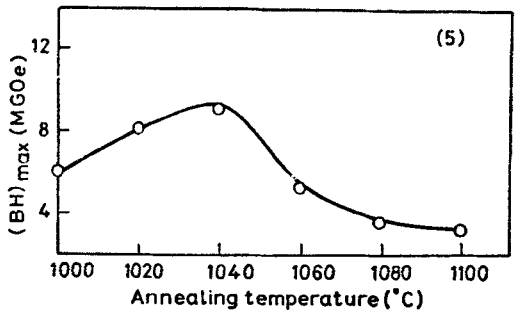


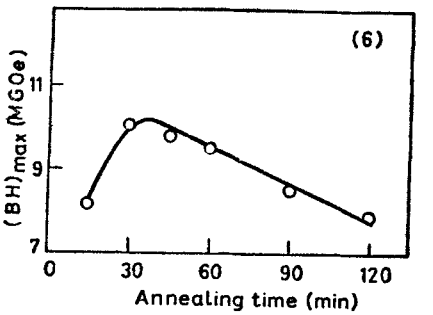
Figures 1 and 2. Variation of H_c with **1.** temperature (60 min); **2.** time at 1020° C.





Figures 3 and 4. Variation of B_r with **3.** temperature (60 min); **4.** time at 1040° C.





Figures 5 and 6. Variation of $(BH)_{max}$ with **5.** temperature (60 min); **6.** time at 1040° C.

magnetic properties in a complex manner and hence precise interpretation of the magnetic behaviour becomes difficult. It is, however, felt that results of such complex reactions occurring during heat treatment in association with the processing variables are responsible for the response of the magnetic properties noted in the mischmetal-cobalt alloy under investigation,

4. Conclusions

The process of solidification of the MM–Co_5 alloy in a magnetic field has yielded magnetic properties like $(BH)_{max}$ 10·3 MGOe, B_r 7 kG and H_c 5 kOe, and the process is expected to be economical compared to other fabrication methods.

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